FORM PTO-1390 (REV. 9-2001) U S DEPARTMENT OF COMMERCE PATENT AND TRADEMARK OFFICE

TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. 371

ATTORNEY 'S DOCKET NUMBER: LAL-C591-US

U S APPLICATION NO (If known, see 37 CFR 1 5): 10/018076

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/GB00/01821	12 May 2000 (12.05.00)	04 June 1999 (04.06.99)

TITLE OF INVENTION: HARD TURNING

APPLICANT(S) FOR DO/EO/US: MANLEY, RILEY

Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. [X] This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. [ ] This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. [ ] This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. [X] The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. [X] A copy of the International Application as filed (35 U.S.C. 371(c)(2))
   a. [ ] is attached hereto (required only if not communicated by the International Bureau).
   b. [X] has been communicated by the International Bureau.
   c. [ ] is not required, as the application was filed in the United States Receiving Office (RO/US).
6. [ ] An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. [ ] is attached hereto.
   b. [ ] has been previously submitted under 35 U.S.C. 154(d)(4).
7. [ ] Amendments to the claims of the International Aplication under PCT Article 19 (35 U.S.C. 371(c)(3))
   a. [ ] are attached hereto (required only if not communicated by the International Bureau).
   b. [ ] have been communicated by the International Bureau.
   c. [ ] have not been made; however, the time limit for making such amendments has NOT expired.
   d. [ ] have not been made and will not be made.
8. [ ] An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371 (c)(3)).
9. [ ] An oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. [ ] An English lanugage translation of the annexes of the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371(c)(5)).

Items 11 to 20 below concern document(s) or information included:

11. [ ] An Information Disclosure Statement under 37 CFR 1.97 and 1.98.
12. [ ] An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
13. [X] A FIRST preliminary amendment.
14. [ ] A SECOND or SUBSEQUENT preliminary amendment.
15. [ ] A substitute specification.
16. [ ] A change of power of attorney and/or address letter.
17. [ ] A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
18. [ ] A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. [ ] A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. [ ] Other items or information:

U.S. APPLICATION NO (if known, see 37 CFR 1.5)	INTERNATIONAL APPLICATION NO	ATTORNEY'S DOCKET NUMBER
10/018076	PCT/GB00/01821	LAL-C591-US

21. ☐ The following fees are submitted:

	CALCULATIONS PTO USE ONLY	
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)):		
Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO **$1040.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO **$890.00**		
International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO **$740.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4) **$710.00**		
International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4) **$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =	$ 890.00	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(e)).	$ 0	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE	$	
Total claims	20 - 20 =	0	x **$18.00**	$ 0	
Independent claims	4 - 3 =	1	x **$84.00**	$ 84.00	
MULTIPLE DEPENDENT CLAIM(S) (if applicable)			+ **$280.00**	$ 0	
TOTAL OF ABOVE CALCULATIONS =				$ 974.00	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2.			+	$	
SUBTOTAL =				$ 974.00	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492(f)).				$	
TOTAL NATIONAL FEE =				$ 974.00	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31). **$40.00** per property +				$	
TOTAL FEES ENCLOSED =				$ 974.00	
				Amount to be refunded:	$
				charged:	$

a. ☐ A check in the amount of $ _____ to cover the above fees is enclosed.

b. ☒ Please charge my Deposit Account No. 50-0760 in the amount of $ 974.00 to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. 50-0760 . A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137 (a) or (b)) must be filed and granted to restore the application to pending status.

SEND ALL CORRESPONDENCE TO:

Daniel C. Stelter, Division IP Counsel
UNOVA UK Ltd., A UNOVA Company
c/o Cincinnati Machine, A UNOVA Company
4701 Marburg Avenue, Cincinnati, Ohio 45209
(513) 841-7032 telephone, (513) 841-7020 facsimile
dan_stelter@cinmach.com e-mail

SIGNATURE

Daniel C. Stelter, Div. IP Counsel
NAME

40,830
REGISTRATION NUMBER

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
WASHINGTON, D.C., UNITED STATES OF AMERICA

In re Application of:

Applicant(s):	**MANLEY, et al.**	
Serial No.:	**(not yet assigned)**	
Filing Date:	**(filed herewith)**	
Int'l Serial No.	**PCT/GB00/01821**	
Int'l Filing Date:	**12 MAY 2000**	
Priority Date:	**04 JUNE 1999**	
Entitled:	**HARD TURNING**	Examiner:
Our File Ref.:	**LAL-C591-US**	Group Art Unit:

PRELIMINARY AMENDMENT UNDER 37 C.F.R. 1.115

Honorable Assistant Commissioner for Patents
United States Patent and Trademark Office
Washington, D.C. 20231

Dear Assistant Commissioner:

Now come Applicants, by counsel, and respectfully submit the following Preliminary Amendment in the above-referenced application, filed herewith under 35 U.S.C. 371.

PRELIMINARY AMENDMENT UNDER 37 C.F.R. 1.115

Please cancel claims 1-24.

Please add the following new claims 25-45, set forth on pages 2-6 hereof, without any markings whatsoever. No new matter has been added. Remarks are submitted respectfully herewith, beginning on page 7 hereof.

25. (New) A turning process in which a cutting tool engages the surface of a rotating component so as to remove a helix of metal therefrom as a result of synchronisation of the relative axial movement of the tool and the component and the rotation of the latter, in which at least the depth of the cut achieved by the tool and component engagement is under the control of a computer which is programmed to increase the depth of cut at intervals during the turning process, so as to create in the turned surface a plurality of depressions which have a marginally smaller radius of curvature than that of the surrounding turned surface.

26. (New) A process according to claim 25 in which the computer is also programmed to control the speed of rotation of the component.

27. (New) A process according to claim 26 wherein the computer is also programmed to control the relative axial movement between the tool and the component.

28. (New) A process according to claim 25 wherein the computer is programmed so as to synchronise the rotation of the component and the axial movement of the tool so that the locus of the point of engagement of the tool and the component is a helix.

29. (New) A process according to claim 25 in which the programming is such as to increase the depth of cut during regularly spaced apart intervals.

30. (New) A process according to claim 29 the timing of the intervals is adjusted from one revolution to the next so that depression do not become aligned parallel to the axis of the

component.

31. (New) A process according to claim 29 in which the timing of the intervals is such as to produce a plurality of depressions around each revolution of the component.

32. (New) A process according to claim 31 the timing of the intervals is adjusted from one revolution to the next so that depression do not become aligned parallel to the axis of the component.

33. (New) A process according to claim 25 wherein the transition between the turned surface of the component and each such depression is gradual and itself generated during more than one revolution of the component, by programming the computer to increase the depth of cut gradually over the said one or more revolutions during which the transition is to occur.

34. (New) A process according to claim 25 wherein at one end of such a depression the computer programme is arranged to reduce the depth of cut in a similar gradual manner over a corresponding number of revolutions of the component, back to that required to produce the turned surface of the component beyond the depression.

35. (New) A process according to claim 25 wherein the component is to taper in overall diameter, and the depth of cut instructions generated by the programme during the transitions and during the generation of each reduced diameter region takes this into account, so that the diameter of the component is progressively reduced during the whole of the turning process.

36. (New) A process according to claim 25 wherein the final surface specification includes a bearing ratio vector requirement, which is achieved by adjusting the rate of change of radius (diameter) at one or both ends of each depression so that the required percentage of component material will exist at the specified depths relative to the peak diameter of the turned surface.

37. (New) A process according to claim 25 wherein a bluing gauge percentage figure has to be complied with, and the computer is programmed to adjust the extent of the depressions relative to the remaining area of the turned component surface, so as to provide a sufficient overall area of turned surface which will be inked by the gauge during a bluing test, relative to the overall area of the depressions which will not normally become inked during the test.

38. (New) A process according to claim 25 wherein the final surface is to be capable of being tested at any point along its axial length, wherein the programme arranged for the depressions to be are evenly distributed over the overall surface of the component to ensure that measurements made on the component will tend to be the same wherever they are made.

39. (New) A process according to claim 25 wherein the component is to be gauged as part of the control of the turning process, wherein the programme organises the computer to store co-ordinates of the depressions and transitions or an algorithm of their generation, so that an appropriate correction can be made to the result of any gauged value of (say) diameter, or the position at which a gauge is to be applied can be determined in advance of the gauging step and the gauge or the component positioned accordingly before the measurement is made.

40. (New) A component when manufactured in accordance with a computer controlled hard turning process as claimed in claim 25.

41. (New) A programmed computer or computer programme for operating a computer, adapted to control the operation of a metal machining process involving the removal of metal from a rotating workpiece by the engagement therewith of the tip of a metal cutting tool, at least the position of which is controlled by the said computer, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth machined surface thereon, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface, during the machining process, plural spaced apart depressions for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding.

42. (New) A metal turning machine in combination with a computer based control system therefore, when programmed to perform a hard turning process on a rotating workpiece involving the removal of metal from the surface thereof by the engagement therewith of the tip of a metal cutting tool, at least the position of which is controlled by the said computer based control system, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface thereon, wherein the programme serves to alter the instantaneous position of the tool during the machining process, so as to introduce into the otherwise smooth surface plural spaced apart depressions, for the purpose of simulating a surface typical of that which would be obtained on the workpiece if the latter had been finished by

grinding.

43. (New) A method or apparatus according to claim 25 further comprising the steps of gauging and/or measuring the machined part during the machining process, to generate signals indicative of one or more dimensions of the machined part, and supplying the signals to the computer, to assist in the control of the machining process.

44. (New) A machine tool in combination with a computer based control system therefore, when programmed to perform a machining process on a rotating workpiece, involving the removal of material from the workpiece by the engagement therewith of a cutting tool, at least the position of which is controlled by the said computer based control system and which, as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface on the machined part, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface of the machined part, plural spaced apart depressions during the machining process, for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding.

45. (New) A machine tool according to claim 44, further comprising at least one gauging or measuring device adapted to perform measurements on the workpiece during the machining process, to generate signals indicative of one or more dimensions of the workpiece, and means for conveying the signals to the computer as feedback signals indicative of how the process is progressing, to assist in the control of the process.

REMARKS

The above-referenced case, filed herewith, is a national stage filing under 35 U.S.C. 371, based upon international patent application serial no. PCT/GB00/01821. The international patent application was filed with thirty-four (34) claims numbered 1-34.

During Chapter II proceedings, Applicants amended the claims under Article 34 of the Patent Cooperation Treaty down to a total of twenty-four (24) claims numbered 1-24, including five (5) independent claims. Amended claims numbered 1-24 were attached as an Annex to the International Preliminary Examination Report dated 29 October 2001 in which the Examiner stated that all claims but claim 15 meet the requirements of novelty, inventive step and industrial applicability. According to the Examiner's reasoned statement, in the Examiner's view, claim 15 meets only the requirement of industrial applicability.

Applicants respectfully note that several of the claims numbered 1-24 are in improper multiple-dependent claim form. In an effort to present the claims in a manner which will facilitate efficient review and allowance by the U.S. Patent and Trademark Office, yet while at the same time intending to preserve the subject matter thereof which the PCT Examiner viewed as meeting the requirements of novelty, inventive step and industrial applicability, Applicants have herewith canceled claims numbered 1-24 and added new claims 25-45 which represent the aforementioned canceled claims numbered 1-24 without use of multiple-dependent claim form.

Applicants respectfully submit that the subject matter contained in claim 15 -- which the PCT Examiner viewed as not meeting the requirements of novelty and inventive step -- has not been copied into any of new claims 25-45 hereof. While not admitting that said claim 15 does indeed fail to meet the requirements of novelty and inventive step, Applicants have nevertheless canceled claim 15 without rewriting it into any of the new claims numbered 25-45 so that timely

Serial No. **(not yet assigned)**
Our Ref. **LAL-C591-US**

disposition of this matter can be made.

Because each of the claims numbered 1-24 have been canceled herein, each of the claims numbered 25-45 remaining in the case are new, and as such, Applicants are not required to file a marked-up version of the new claims. 37 C.F.R. 1.121(c)(1)(ii).

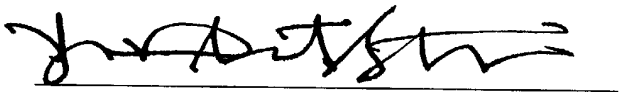
Applicants respectfully submit that -- as established by the International Preliminary Examination Report -- claims numbered 25-45 submitted herewith are in condition for allowance and respectfully request the Examiner to pass said claims 25-45 on to allowance.

Should the Examiner have any questions concerning the above, or believe that issues remain in the case, Applicants respectfully request the Examiner to contact their undersigned counsel, who may be reached by telephone to (513) 841-7032.

Respectfully submitted,

ROBERT S. MANLEY, Applicant
JOHN M. RILEY, Applicant

Date: 04 Dec. 2001

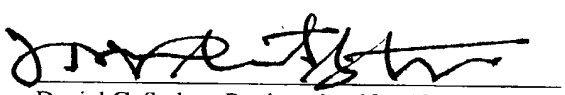


Daniel C. Stelter, Reg. No. 40,830
Counsel for Applicants

UNOVA U.K. Ltd., A UNOVA Company
c/o Cincinnati Machine, A UNOVA Company
4701 Marburg Avenue, Cincinnati, Ohio 45209
(513) 841-7032 phone, (513) 841-7020 fax

CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.10

The undersigned hereby certifies that a true and accurate copy of the foregoing "Preliminary Amendment Under 37 C.F.R. 1.115" is being deposited with the U.S. Postal Service, "Express Mail Post Office to Addressee" service, in an enveloped addressed to the Hon. Ass't Comm'r for Patents, United States Patent and Trademark Office, Box PATENT APPLICATION, Washington, D.C. 20231, bearing U.S.P.S. "Express Mail" Label Number **EL245144963US**, on this the 4th day of December, 2001.



Daniel C. Stelter, Registration No. 40,830

HARD-TURNING

Field of invention

This invention concerns the formation of surface finishes in machined components and applies both to internal and external surfaces.

Background to the invention

The surfaces of metal components hitherto surface-finished by a grinding process, have been specified by means of measurements which can be performed on the components as they are manufactured.

Typically these measurements have involved size tolerance at a particular position along the length of the component, an acceptable variation in the height of peaks to troughs in the surface when measured along a single line along the component, known as the Ra measure, and the bearing ratio of the peaks and troughs at one or more depths from the peaks. This last measurement may be required to lie between a maximum and a minimum percentage of the length of the line.

Overall flatness has often been measured in terms of the percentage of the area of the surface which will be inked by a standard bluing gauge.

All other things being equal, provided the measurements on production components fall within the specification set down as acceptable by the designer, the components will be expected to function correctly for the purpose they are intended. Thus for example surface finish specifications may be laid down for the bores in fuel injectors for diesel engines and for the cones for synchronous meshing of gears in transmission units.

Generally the surface finishing of such components has been achieved by grinding processes which, although superficially leaving a very smooth surface finish, in fact leave a pitted surface (at the micron level) since the removal of the metal is achieved by each piece of grit in the surface of the grinding wheel gouging out a tiny portion of the metal, with the relative rotation of the wheel and the component. The grit contact with the metal is relatively random and arbitrary since the grit is not uniform in size and distribution and the result is a surface having a large number of tiny pockets relatively randomly distributed over the area of the surface.

It has been proposed to replace the grinding finishing step for such components with precision turning, sometimes referred to as hard turning. It is an object of the present invention to provide a process and apparatus for achieving a machined surface finish which, to a first approximation, is within the specification laid down for the component when finished by grinding. In this way, for example turned components can be compared alongside components produced by conventional techniques.

In addition if, as may be the case, the life and/or functionality of certain components is dependent on the type of surface produced by grinding, the method of the invention will go some way to ensuring that the life and/or functionality of such components when machined, eg by hard turning, is similar to that of the ground components.

Summary of the invention

According to one aspect of the present invention in a turning process in which a cutting tool engages the surface of a rotating component so as to remove a helix of metal therefrom as a result of synchronisation of the relative axial movement of the tool and the component and the rotation of the latter, at least the depth of cut achieved by the tool and component engagement is under the control of a programmed computer.

The computer may also be programmed to control the speed of rotation of the component.

The computer may also be programmed to control the relative axial movement between the tool and the component.

Typically the tool is moved axially relative to the component so as to progress the point of engagement between the tool and the surface of the component along the length of the latter as the component rotates.

Preferably the computer is programmed so as to synchronize the rotation of the component and the axial movement of the tool so that the locus of the point of engagement of the tool and the component is a helix.

Preferably the axial movement of the tool is synchronised with the rotation of the component so that the angle of the helix is such as to just advance the tool by the thickness of its cutting tip during each revolution, so that not only is a continuous helix of metal peeled away from the surface of the component as the machining progresses but a smooth surface is left behind.

If a taper is required in the component the depth of cut may be increased progressively with axial advance of the tool relative to the component, however the increasing depth of cut would still normally be controlled so as to produce a smooth surface, albeit of progressively reducing diameter.

In accordance with an important aspect of the invention, in a process of producing a component by metal removal by turning whilst the surface of the component is engaged by the tip of a cutting tool, so as to progressively remove a helix of metal from the surface of the component and thereby produce at least in the region of the cut a cylindrical surface the radius of which is determined by the position of the tool relative to the axis of rotation of the component, and in which the tool is under computer control at least as to its position for determining the

depth of cut and therefore the radius of the turned surface of the component, the computer is programmed to increase the depth of cut at intervals during the turning process so as to create a plurality of depressions in the turned surface of the component which have a marginally smaller radius of curvature than that of the surrounding turned surface.

The programming may be such as to increase the depth of cut during regularly spaced apart intervals.

The timing of the intervals may such that at least one depression is created during at least a part of each revolution of the component.

The timing may be such as to produce a plurality of depressions around each revolution of the component.

The timing of the intervals may be adjusted from one revolution to the next so that depressions do not become aligned parallel to the axis of the component.

The timing of the intervals may be selected so as to produce a regular or random or pseudo random pattern of depressions in the component surface.

Each interval may be of the same duration so that each depression is of the same extent, or a variation may be introduced into the duration of each of the intervals so that the depressions are of correspondingly different size.

In a preferred method each interval is arranged to extend over a plurality of consecutive revolutions of the component so that each resulting depression comprises an annular region of reduced diameter.

The transition between the turned surface of the component and each such annular depression may be gradual and itself may be generated during more than one revolution of the component, by

programming the computer to increase the depth of cut gradually over the said one or more revolutions during which the transition is to occur. At the other end of such an annular depression the computer programme may be arranged to reduce the depth of cut in a similar gradual manner over a corresponding number of revolutions of the component, back to that required to produce the turned surface of the component beyond the annular depression.

Where the component is to taper in overall diameter, the depth of cut instructions generated by the programme during the transitions and during the generation of each reduced diameter annular region must take this into account, so that diameter of the component is progressively reduced during the whole of the turning process.

Since the depressions are merely to break-up what would otherwise be a smooth surface produced by the turning process, the depth of each depression relative to the surrounding turned surface will normally need only to be very small. Differences in radius as between the base of each depression and the surrounding turned surface may be of the order of 1 micron or less. Where more significant surface break-up is desired the difference in radius may be of the order of 2 or 3 microns or more.

Depending on the properties required of the final surface the programming of the computer may be such as to produce relatively small but relatively deep depressions per unit area of the component surface or relatively large but relatively shallow depressions over the same surface area.

Likewise the number of depressions per unit area of the component surface may be adjusted to produce the desired characteristics in the final surface.

Where the final surface specification includes a bearing ratio vector requirement, the latter may be achieved by adjusting the rate of change of radius (diameter) at one or both ends of each

depression so that the required percentage of component material will exist at the specified depths relative to the peak diameter of the turned surface.

Where a bluing gauge percentage figure has to be complied with, the computer may be programmed to adjust the extent of the depressions relative to the remaining area of the turned component surface, so as to provide a sufficient overall area of turned surface which will be inked by the gauge, during the bluing test, relative to the overall area of the depressions, which will not normally become inked during the test.

Where the final surface is to be capable of being tested at any point along its axial length, the programme should arrange that the depressions are evenly distributed over the overall surface of the component to ensure that measurements made on the component will tend to be the same wherever they are made.

Where the component is to be gauged as part of the control of the turning process, it is desirable that the precise positions of the depressions and any transitions between depression and main turned surface are known and to this end the programme advantageously organises the computer to store co-ordinates of the depressions and transitions or an algorithm of their generation, so that an appropriate correction can be made to the result of any gauged value of (say) diameter, or the position at which a gauge is to be applied may be determined in advance of the gauging step and the gauge or the component positioned accordingly before the measurement is made.

The invention also lies in a component when manufactured in accordance with a computer controlled hard turning method as proposed by the invention disclosed herein.

The invention also lies in a metal turning machine and computer control therefor programmed to perform a hard turning operation in accordance with the invention.

The invention also lies in a metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a component in accordance with the invention.

The invention also lies in a computer when programmed to control a metal working machine so as to perform a hard turning operation on a component such as described herein.

The invention also lies in a programme adapted to operate a computer so as to provide control signals for a metal working machine to cause the latter to perform a hard turning operation such as described herein.

The invention also lies in a computer programme for operating a computer so as to control a metal working machine to perform a hard turning operation on a component such as described herein, when stored on a data carrier.

The invention also lies in a computer programme for operating a computer, or a programmed computer, adapted to control the operation of a metal machining process involving the removal of metal from a rotating workpiece by the engagement therewith of the tip of a metal cutting tool at least the position of which is controlled by the said computer, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth machined surface thereon, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface, during the machining process, plural spaced apart depressions for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding.

The invention also lies in a metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a rotating workpiece involving the removal of metal from the surface thereof by the engagement therewith of the tip of a metal cutting tool at least

the position of which is controlled by the said computer based control system, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface thereon, wherein the programme serves to alter the instantaneous position of the tool during the machining process, so as to introduce into the otherwise smooth surface plural spaced apart depressions, for the purpose of simulating a surface typical of that which would be obtained on the workpiece if the latter had been finished by grinding.

The invention also lies in a method or apparatus as aforesaid which further comprises gauging and/or measuring the machined part during the machining process, to generate signals indicative of one or more dimensions of the machined part, and supplying the signals to the computer, to assist in the control of the machining process.

The invention also lies in a metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a rotating workpiece, involving the removal of metal from the rotating workpiece by the engagement therewith of the tip of a metal cutting tool, at least the position of which is controlled by the said computer based control system and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface on the machined part, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface of the machined part, plural spaced apart depressions during the machining process, for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding, and the machine includes at least one gauging or measuring device adapted to perform measurements on the machined part during the machining process, to generate signals indicative of one or more dimensions of the machined part, and means for conveying the signals to the computer as feedback signals indicative of how the process is progressing, to assist in the control of the process.

Examples of components which may be made in accordance with the invention.

Synchro cones for gearboxes have hitherto been formed by grinding to a particular surface and taper diameter specification. In a method in accordance with the invention of hard turning such a component so as to have a surface which will fall within the previous specification for the component, using a computer controlled metal turning process as aforesaid, the computer was programmed so as to introduce into the turned surface a plurality of annular depressions having a depth relative to the turned surface of 1 micron, pitched at 1mm spacings along the axial length of the component. Each depression extended over a total axial distance of 0.2mm with a transition involving a gradual change in radius extending over 0.02mm at each side of the depression (within the 0.2mm width), so that the base of the depression, which lay a full 1 micron below the turned surface at either end, extended over less than the 0.2mm width of the depression.

Other examples of a similar component involved the formation therein of similar depressions having the same overall axial extent and similar transitions, but with depths of 2 microns and 3 microns respectively, for comparison purposes.

Injector bores for fuel injectors for diesel engines have to be internally finished to a high accuracy and have hitherto been ground to achieve the desired finish and diameter. The invention offers an alternative manufacturing process for such injectors in which the bores are hard turned under computer control in accordance with the invention and have depressions formed in their internal surfaces to produce a surface having appropriate characteristics to conform to the original specification for the product when internally ground.

The invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a perspective view of a synchromesh gear for an automotive manual gear box, and having an external cone formed by a turning process in accordance with the present invention;

Figure 2 is a magnified plan view of depressions formed in the surface of the cone shown in Figure 1; and

Figure 3 is a diagram in section (not to scale) showing the depressions of Figure 2.

The synchromesh gear shown in Figure 1 has a short external taper 10 which is formed on a precision lathe, operating in accordance with the process of the invention. The lathe may be a hard turning lathe Type DT40 made by Landis Lund (a division of UNOVA UK Limited) of Cranfield, England. For further details of such a machine tool or precision lathe, reference may be made to published International Patent specification WO97/30381.

The computer programme which controls the lathe for forming the taper 10, is arranged to introduce minute annular depressions in the otherwise relatively smooth surface of the taper 10. Three such depressions in the surface of the taper, are shown at 12, 14 and 16 in the magnified plan view of Figure 2, which is enlarged 35 times.

For a clearer view of the depressions, reference is made to the section shown in Figure 3, in which typically each depression has a depth of 1 micron, a base width of 0.16mm, and an overall width of 0.2mm which merges down to the base at each side over a width of 20 microns. The distance or pitch between depressions is approximately 1.0mm.

Although the invention has been described primarily with reference to hard turning, it is applicable generally to any machining process where the surface is generated by metal cutting. It could therefore also be applied to boring, eg jig boring, and even to CNC form milling using a round-nosed cutter.

Claims

1. A turning process in which a cutting tool engages the surface of a rotating component so as to remove a helix of metal therefrom as a result of synchronisation of the relative axial movement of the tool and the component and the rotation of the latter, in which at least the depth of the cut achieved by the tool and component engagement is under the control of a programmed computer.

2. A process according to claim 1 in which the computer is also programmed to control the speed of rotation of the component.

3. A process according to claim 1 or claim 2 in which the computer is also programmed to control the relative axial movement between the tool and the component.

4. A process according to any preceding claim in which the tool is moved axially relative to the component so as to progress the point of engagement between the tool and the surface of the component along the length of the latter as the component rotates.

5. A process according to claim 4 in which the computer is programmed so as to synchronize the rotation of the component and the axial movement of the tool, so that the locus of the point of engagement of the tool and the component is a helix.

6. A process according to claim 5 in which the axial movement of the tool is synchronised with the rotation of the component so that the angle of the helix is such as to just advance the tool by the thickness of its cutting tip during each revolution, so that not only is a continuous helix of metal peeled away from the surface of the component as the machining progresses but a smooth surface is left behind.

7. A process according to any one of claims 4 to 6 in which a taper is required in the component, and the apparent depth of the cut is increased progressively with axial advance of the tool relative to the component, the increasing depth of cut still being normally controlled so as to produce a smooth surface, albeit of progressively reducing diameter.

8. A process according to any one preceding claim in which the computer is programmed to increase the depth of cut at intervals during the turning process so as to create a plurality of depressions in the turned surface of the component which have a marginally smaller radius of curvature than that of the surrounding turned surface.

9. A process according to claim 8 in which the programming is such as to increase the depth of cut during regularly spaced apart intervals.

10. A process according to claim 9 in which the timing of the intervals is such that at least one depression is created during at least a part of each revolution of the component.

11. A process according to claim 9 or claim 10 in which the timing is such as to produce a plurality of depressions around each revolution of the component.

12. A process according to any one of claims 9 to 11 in which the timing of the intervals is adjusted from one revolution to the next so that depression do not become aligned parallel to the axis of the component.

13. A process according to any one of claims 9 to 12 in which the timing of the intervals is selected so as to produce a regular or random or pseudo random pattern of depressions in the component surface.

14. A process according to any one of claims 9 to 13 in which each interval is of the same duration so that each depression is

of the same extent, or in which a variation is introduced into the duration of each of the intervals so that the depressions are of correspondingly different size.

15. A process according to any one of claims 9 to 14 in which each interval is arranged to extend over a plurality of consecutive revolutions of the component so that each resulting depression comprises a helical region of reduced diameter.

16. A process according to any one of claims 8 to 15 in which the transition between the turned surface of the component and each such depression is gradual and itself generated during more than one revolution of the component, by programming the computer to increase the depth of cut gradually over the said one or more revolutions during which the transition is to occur.

17. A process according to any one of claims 8 to 16 in which at one end of such a depression the computer programme is arranged to reduce the depth of cut in a similar gradual manner over a corresponding number of revolutions of the component, back to that required to produce the turned surface of the component beyond the depression.

18. A process according to any one of claims 8 to 17 in which the component is to taper in overall diameter, and the depth of cut instructions generated by the programme during the transitions and during the generation of each reduced diameter region takes this into account, so that the diameter of the component is progressively reduced during the whole of the turning process.

19. A process according to any one of claims 8 to 18 in which the differences in radius as between the base of each depression and the surrounding turned surface are of the order of 1 micron or less.

20. A process according to any one of claims 8 to 19, in which the final surface specification includes a bearing ratio vector

requirement, which is achieved by adjusting the rate of change of radius (diameter) at one or both ends of each depression so that the required percentage of component material will exist at the specified depths relative to the peak diameter of the turned surface.

21. A process according to any one of claims 8 to 20, in which a bluing gauge percentage figure has to be complied with, and the computer is programmed to adjust the extent of the depressions relative to the remaining area of the turned component surface, so as to provide a sufficient overall area of turned surface which will be inked by the gauge during a bluing test, relative to the overall area of the depressions which will not normally become inked during the test.

22. A process according to any one of claims 8 to 21, in which the final surface is to be capable of being tested at any point along its axial length, wherein the programme is arranged for the depressions to be evenly distributed over the overall surface of the component to ensure that measurements made on the component will tend to be the same wherever they are made.

23. A process according to any one of claims 8 to 22, in which the component is to be gauged as part of the control of the turning process, wherein the programme organises the computer to store co-ordinates of the depressions and transitions or an algorithm of their generation, so that an appropriate correction can be made to the result of any gauged value of (say) diameter, or the position at which a gauge is to be applied can be determined in advance of the gauging step and the gauge or the component positioned accordingly before the measurement is made.

24. A component when manufactured in accordance with a computer controlled hard turning method as claimed in any one preceding claim.

25. A metal turning machine and computer control therefor programmed to perform a hard turning operation in accordance with

any one of claims 1 to 23.

26. A metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a component in accordance with any one of claims 1 to 23.

27. A computer when programmed to control a metal working machine so as to perform a hard turning process according to any one of claims 1 to 23 on a component.

28. A programme adapted to operate a computer so as to provide control signals for a metal working machine to cause the latter to perform a hard turning process according to any one of claims 1 to 23.

29. A computer programme when stored on a data carrier for operating a computer so as to control a metal working machine to perform a hard turning process on a component according to any one of claims 1 to 23.

30. A programmed computer or a computer programme for operating a computer, adapted to control the operation of a metal machining process involving the removal of metal from a rotating workpiece by the engagement therewith of the tip of a metal cutting tool, at least the position of which is controlled by the said computer, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth machined surface thereon, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface, during the machining process, plural spaced apart depressions for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding.

31. A metal turning machine in combination with a computer based control system therefor, when programmed to perform a hard turning process on a rotating workpiece involving the removal of

metal from the surface thereof by the engagement therewith of the tip of a metal cutting tool, at least the position of which is controlled by the said computer based control system, and which as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface thereon, wherein the programme serves to alter the instantaneous position of the tool during the machining process, so as to introduce into the otherwise smooth surface plural spaced apart depressions, for the purpose of simulating a surface typical of that which would be obtained on the workpiece if the latter had been finished by grinding.

32. A method or apparatus according to any one preceding claim, which further comprises gauging and/or measuring the machined part during the machining process, to generate signals indicative of one or more dimensions of the machined part, and supplying the signals to the computer, to assist in the control of the machining process.

33. A machine tool in combination with a computer based control system therefor, when programmed to perform a machining process on a workpiece, involving the removal of material from the workpiece by the engagement therewith of a cutting tool, at least the position of which is controlled by the said computer based control system and which, as a result of synchronised relative movement between the tool and the workpiece, would produce a smooth surface on the machined part, wherein the programme serves to alter the instantaneous position of the tool so as to introduce into the otherwise smooth surface of the machined part, plural spaced apart depressions during the machining process, for the purpose of simulating a surface typical of that which would be obtained thereon if the latter had been finished by grinding.

34. A machine tool according to claim 33, further comprising at least one gauging or measuring device adapted to perform measurements on the workpiece during the machining process, to generate signals indicative of one or more dimensions of the workpiece, and means for conveying the signals to the computer

workpiece, and means for conveying the signals to the computer as feedback signals indicative of how the process is progressing, to assist in the control of the process.

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(71) Applicant *(for all designated States except US)*: **UNOVA U.K. LIMITED** [GB/GB]; 26 Temple Street, Aylesbury, Buckinghamshire HP20 2RQ (GB).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **MANLEY, Stephen, Robert** [GB/GB]; 48 The Planes, Kempston, Bedford MK42 7JU (GB). **RILEY, Martin, John** [GB/GB]; 20 Ashville Terrace, Crosshills, Keighley, West Yorkshire BD20 7LQ (GB).

(74) Agent: **KEITH W NASH & CO.**; 90-92 Regent Street, Cambridge CB2 1DP (GB).

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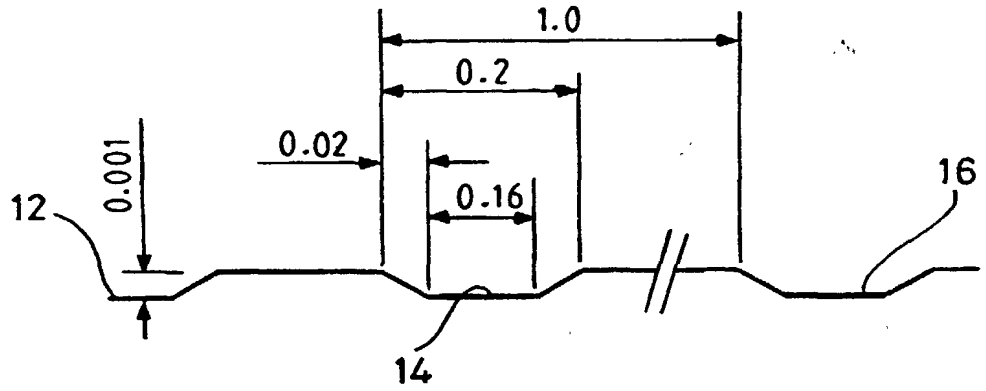


TYPICAL SURFACE MODIFICATION
(MILLIMETRES, NOT TO SCALE)

(57) Abstract: A metal machining process, in particular hard turning using a computer controlled precision lathe, comprises the step of controlling the tool to increase the depth of cut at intervals during machining, so as to create a plurality of depressions (12 to 16). As applied to a synchromesh cone (10), for example, the depressions may typically be annular and 1 micron in depth, with a base width of 0.16 mm and spaced at 1.0 mm along the taper. The process enables components to be produced whose surface is similar to that of ground components.

WO 00/74882 A1

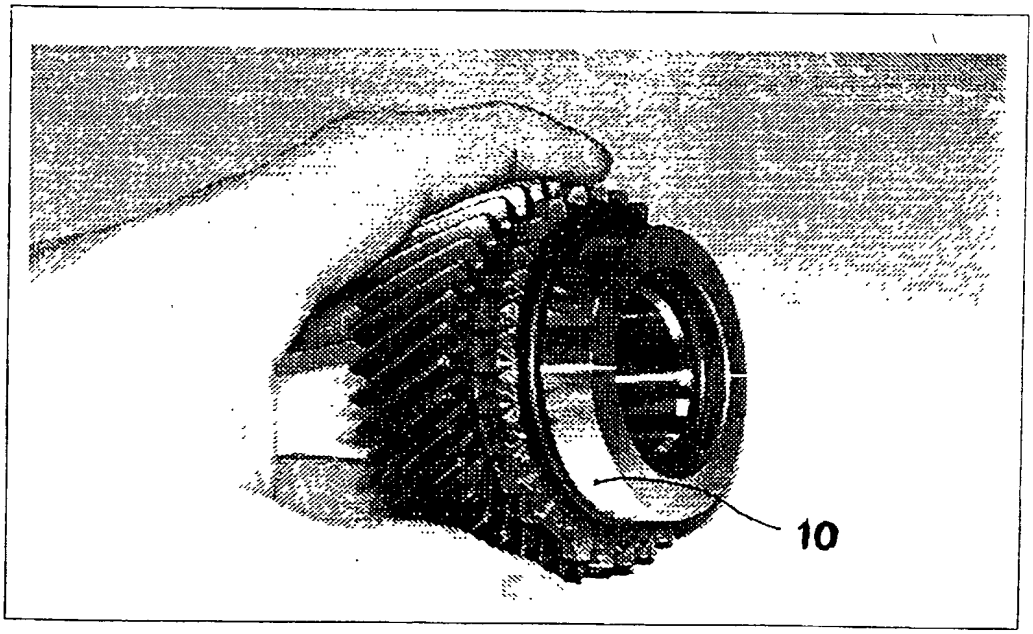
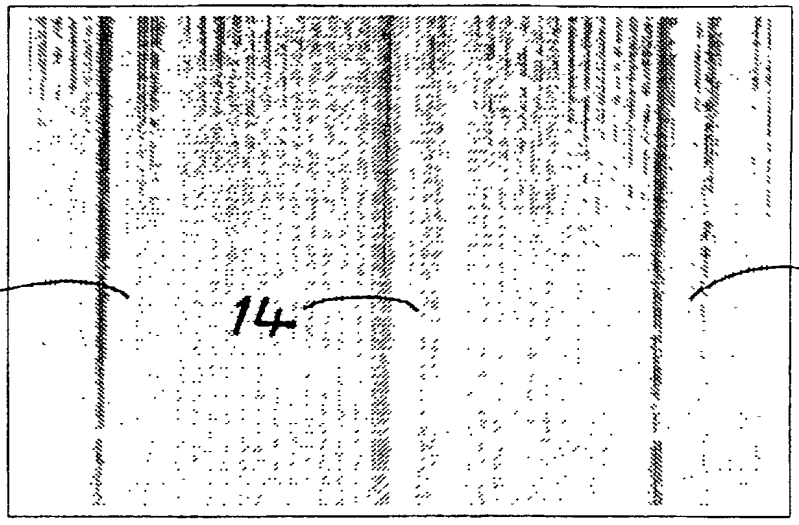
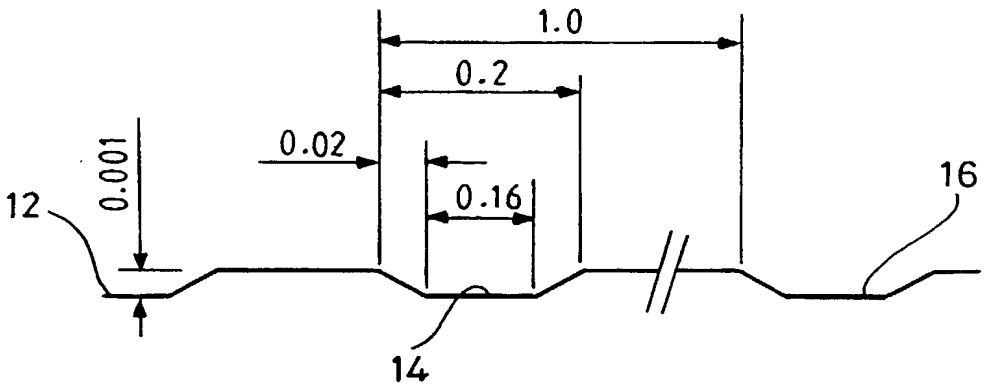


Fig. 1



Magnified view of surface
scale 35:1

Fig. 2



TYPICAL SURFACE MODIFICATION
(MILLIMETRES, NOT TO SCALE)

Fig. 3

DECLARATION UNDER 37 C.F.R. § 1.63 AND APPOINTMENT OF POWER OF ATTORNEY

As a below-named inventor, I hereby declare the following:

- My residence, post office address and citizenship are as stated below, next to my name.

- I believe that I am an original, first and sole inventor (if only one name is listed below) or joint inventor (if more than one name is listed below) of the subject matter which is claimed and for which a patent is sought on an invention entitled "HARD TURNING", the specification of which: (check one)

  ✔ is attached hereto
  _____ was filed on _____
  as application number _____
  and was amended on _____

- I authorize my below-named attorneys to indicate in the spaces above whether the invention is described and claimed in an attached specification and to provide and enter the filing date and serial number of any corresponding U.S. patent application, if previously filed, and the date of any amendment made thereto without further authorization from me.

- I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred-to above.

- I acknowledge my duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, Section 1.56.

- I hereby claim foreign priority benefits under Title 35, United States Code, Sections 119(a)-(d) of any foreign application(s) for patent or inventor's certificate listed below, and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s)			Priority Claimed	
9912893.6	GB	06/04/99	✔	
Number	Country	Filing Date (Month/Day/Year)	Yes	No
PCT/GB00/01821	WO	05/12/00	✔	
Number	Country	Filing Date (Month/Day/Year)	Yes	No

- I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56 which occurred between the filing date of the prior application and the national or other PCT international filing date of this application:

Application	Filing Date	Status
(Serial Number)	(Month/Day/Year)	(pending, abandoned, issued)
(Senal Number)	(Month/Day/Year)	(pending, abandoned, issued)

▸ I hereby claim domestic priority benefits under Title 35, United States Code, Section 119(e) of any United States Provisional Patent Application(s) listed below:

Application Number	Filing Date

▸ I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with knowledge that willful false statements and the like are made punishable by fine or imprisonment, or both, under Title 18, United States Code, Section 1001 and that such willful false statements may jeopardize the validity of the application of any patent issued thereon.

▸ I hereby appoint the following individuals, as my attorneys, to prosecute this application and to transact all business in the U.S. Patent and Trademark Office connected therewith: M. Michael Carpenter, Registration No. 22,790; Brian L. Ribando, Registration No. 27,109; and, Daniel C. Stelter, Registration No. 40,830.

▸ I hereby request that all communications concerning this application be addressed to:

Daniel C. Stelter, Division IP Counsel
Cincinnati Machine, A UNOVA Company
4701 Marburg Avenue, Cost Center ACM
Cincinnati, Ohio 45209
(513) 841-8100 telephone, (513) 841-7020 facsimile
dan_stelter@cinmach.com electronic mail

× _____ × 11/12/01
Signature of First Inventor — Date

Stephen Robert Manley — GB
Typed Name of First Inventor — Country of Citizenship

48 The Planes, Kempston, Bedford MK42 7JU, Great Britain GBX
Residence and/or Post Office Address (the same if only one address is listed, please indicate separately if not the same)

× M. J. Riley × 5/11/01.
Signature of Second Inventor — Date

Martin John Riley — GB
Typed Name of Second Inventor — Country of Citizenship

20 Ashville Terrace, Crosshills, Keighley, West Yorkshire BD20 7LQ, Great Britain GBX
Residence and/or Post Office Address (the same if only one address is listed, please indicate separately if not the same)

_____ _____
Signature of Third Inventor — Date

_____ _____
Typed Name of Third Inventor — Country of Citizenship

_____
Residence and/or Post Office Address (the same if only one address is listed, please indicate separately if not the same)